The Development of a Remote Sensor System and Decision Support Systems Architecture to Monitor Resistance Development in Transgenic Crops

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The United States Environmental Protection Agency (EPA) has declared that "significant benefits accrue to growers, the public, and the environment" from the use of transgenic pesticid al crops due to reductions in pesticide usage for crop pest management. Large increases in the global use of transgenic pesticidal crops has reduced the amounts of broad spectrum pesticides used to manage pest populations, improved yield and reduced the en vironmental impact of crop management. A significant threat to the continued use of this technology is the evolution of resistance in insect pest populations to the insecticidal Bt toxins expressed by the plants. Management of transgenic pesticidal crops w ith an emphasis on conservation of Bt toxicity in field populations of insect pests is important to the future of sustainable agriculture. A vital component of this transgenic pesticidal crop management is establishing the proof of concept basic understanding, situational awareness, and monitoring and decision support system tools for more than 133650 square kilometers (33 million acres) of bio-engineered corn and cotton for development of insect resistance . Early and recent joint NASA, US EPA and ITD remote imagery flights and ground based field experiments have provided very promising research results that will potentially address future requirements for crop management capabilities.

Key Words: Genetically Modified Crops; Decision Support System; Remote Sensing; Pest Infestation; Ecosystem

1. Introduction

In recent years, the use of Plant Incorporated Protectant (PIP) maize by United States producers has been increasing dramatically. PIP maize contains genetically inserted traits that produce toxins in the plant that provide narrowly targeted protection against specific insect pests. The plant producing toxins offer significant reductions in the application of broad-spectrum pesticides that have ecological and human health consequences. PIP maize as a percentage of total maize acreage planted in the US is expected to continue to increase as these protective traits are "stacked" with other desirable traits by seed companies, and producers are seeing considerable increases in yield as a result. The introduction of maize as a bio-fuel source for ethanol has increased production demand by 4 million hectares. The United States Environmental Protection Agency (USEPA), which is responsible for the registration of PIP crops u nder the Federal Insecticide, Fungicide and Rodenticide Act, views the use of PIP maize as positive. Broad spectrum pesticide use has declined since the PIP traits have been introduced. As the agricultural landscape experiences a higher percentage of maize acres using the PIP technology, the risk of the targeted insect pest populations developing resistance to the toxins, thereby rendering them useless will increase as well [1].This result would negate the effectiveness of the PIP maize traits and could reduce production of a US field maize crop valued at $33 billion dollars in 2006 and place US food and now energy security at risk [2].

Concerns over insect pest resistance development to PIP traits have led the USEPA to team with NASA and the Institute for Technology Development (ITD), to develop imagery systems and geo-spatial technologies which will proactively monitor the maize landscape for resistance development. USEPA developed geo-spatial resistance prediction models are being combined with NASA developed remote sensing products to monitor the maize landscape for resistance development. The two agencies have entered into an interagency agreement which could potentially lead to the development of next generation NASA sensors that will more specifically address the requirements of the USEPA's pest resistance and crop management development strategy.

2. Approach

Since 2004 the Environmental Protection Agency, the Institute for Technology Development, and the National Aeronautics and Space Administration have been collaborating in joint research and development efforts to investigate the use of remote sensing imagery to evaluate potential environmental risk and management options that address ecosystem concerns within a variety of environmental settings including the use of genetically modified crops.

A specific sensor technology goal for this research activity has been the development and use of a unique hyperspectral imager system to perform multiple field experiment measurements. The sensor system is contributing to the scientific knowledge of analysis techniques for potentially managing insect resistance to transgenic crops by improving current crop monitoring and analysis technologies. The initial research objectives have focused on the proof of concept through the use of flight experiment field studies to detect pest infestation in Bacillus thuringiensis (Bt) corn crop plants using remote sensing. The increasing production demand placed on the cultivation of corn by the US bio-energy program highlights the importance of the crop as a food and energy source. The US field corn crop was valued at $33 billion dollars in 2006, planted on more than 28 million hectares and any threat to the continued dependability of crop yield becomes an important factor for the global economy. Increased corn prices fueled by the emerging ethanol market in 2006 attracted more growers to plant the crop on larger acreage with significant changes to agronomic practice. The genetically modified corn varieties, accounting for 40% of the corn planted in 2006, provide pesticidal protection that is narrowly targeted to specific pests and offer significant reductions in the application of broad - spectrum pesticides that have ecological and human health consequences.

Crop monitoring is necessary to avoid failure conditions related to pest resistance. The seed industry has developed a resistance monitoring program that samples insects from four discrete areas of the US corn production landscape. It is widely recognized that pest infestation begins as a local phenomena. To identify local problems and provide comprehensive risk management decision support capabilities to address this ecosystem situation , a proactive monitoring system must be able to observe the extensive corn monoculture in the production landscape and not just the resistance effects of small planted sections. In a nationwide operational environment, the expansiveness of the crop landscape and the dynamic changes of the crop conditions require consideration and development of a concept for a new decision support system architecture approach potentially supported by the use of remote sensor monitoring systems from aircraft, unmanned autonomous vehicles, and even satellite observation platforms . A series of multi-year growing season aircraft platform joint EPA, NASA and ITD field experiments have been the basis for the first phase of defining and developing an understanding of the first principles, the situational awareness requirements, the monitoring considerations, and the nature of decision support tool considerations.

2.1. Field Experiments

During the 2004 and 2005 growing seasons, flight and ground truth studies were conducted at several sites across the corn belt of the USA to evaluate the use of the remotely sensed imagery for the detection of transgenic and European corn borer infested corn hybrids. A number of statistical and image analysis techniques were used to evaluate the imagery's ability to distinguish the transgenic corn hybrids from non-transgenic hybrids and delineate infested crop plots.

Recent flight experiments efforts conducted in 2006 and 2007 over entire field level crop plantings focused on the rapid production of infestation and transgenic delineation maps from the imagery using algorithms developed from the 2004 and 2005 plot level experiments. Throughout the season, the Institute for Technology Development delivered maps identifying potential infestation sites and transgenic/non-transgenic field delineations in a pseudo -operational manner. Ground based researchers visited correlation measurement locations and tested for accurate delineation using assays and infestation measurements.

4. Results and Conclusions

Identification accuracies greater than 90% at the plot scale were obtained using these methods. Accuracies typically improved with increasing algorithm complexity and were highest when comparing individual transgenic hybrids to multiple non - transgenic hybrids.

The use of remote sensing to monitor insect resistance to genetically modified crops holds promise. As more hectares of land are planted to transgenic corn and soybeans to meet food, feed and fuel needs, while at the same time future generations of insects build a resistance to these transgenics, a time may come where an early warning system is need to identify and map the location and extent of insect damage. Imagery from current and future aircraft and satellites platforms provided by NASA and the commercial sector could be a potential data source for a large scale monitoring system. Automated image analysis techniques being developed by this project, and other NASA and EPA projects, could play a key role in such a system.

5. References

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